does not give us a true measure of the amount of heat received from the sun, or of the transparency of the atmosphere, unless it be used in the proper manner. If we merely allow the temperature of any inclosed thermometer to rise to the highest point it can reach, we observe maximum temperatures that depend so entirely upon the peculiarities of the hot box itself and of the wind that happens to be blowing, that no important results can be attained.

The hot box first used by Herschel, de Saussure, and other physicists of the last century, was early in this century replaced by Sir John Herschel's form of the actinometer and, subsequently, by the so-called black-bulb thermometer, which latter was improved by inclosing it in a thin spherical glass bulb inclosing a vacuum. To Arago we owe the addition of the twin black-bulb thermometer in vacuo. For a long time, and even now by English makers, the maximum self-registering thermometer was used, but in the properly constructed system devised by Marie Davy, and now known throughout the world as the Arago-Davy actinometer, both thermometers are delicate, spherical-bulb thermometers, of high grade of accuracy. The ordinary method of using this instrument is to take a series of readings when the two thermometers are exposed side by side in the open sunshine and have attained to comparatively stationary readings. The complete theory of this instrument and the proper method of calculating the results are fully given in the third section of Prof. William Ferrel's memoir Temperature of the Atmosphere and Earth's Surface, published in 1884 as No. XIII of the Professional Papers of the Signal Service. Each of the twin thermometers in vacuo attains a stationary reading when the heat received by radiation, absorption, and conduction equals that carried away by radiation and conduction. Since the two thermometers have surfaces of different absorptive powers and, therefore, different coefficients of reflection and radiation, the sunshine effects each differently, and we can, by considering a series of observations at different hours of the day, determine at once the amount of absorption of the atmosphere and the intensity of the sunshine.

In 1883 the Editor constructed and experimented with an Arago-Davy actinometer in which the thermometers were alternately shaded and exposed. Similar apparatus was taken to Russia by Mr. Rotch for use during the total solar eclipse. The same principle is embodied in Angström's and Chwolson's forms of the pyrheliometer which are described in an article by Chwolson, pages 71–75 of Bulletin No. 11, Report of the Chicago Meteorological Congress of 1893, to which the reader is referred for further details. The Arago-Davy, or the Pouillet apparatus, when properly used, gives crude approximations, but the Chwolson method gives fairly accurate results. The works of Crova, Angström, Chwolson, and Ferrel are to be commended to those who have the requisite skill in experimentation.

DESTRUCTIVE FROST OF JUNE 30, 1899, IN OHIO.

Mr. J. Warren Smith gives in his Climate and Crop report for June some account of the interesting destructive frost on the morning of June 30, in Ohio. He says:

> The interesting features in connection with this frost are its severity so late in the season and the limited area affected. A strong wind prevailed over most of the State, but there must have been wind-breaks sufficient to produce a calm over this great level district known as the Scioto Marsh. Under the clear sky the surface of the ground and of the plants lost heat rapidly by radiation, and in turn cooled the still air in contact with them, until just at the surface of the earth the temperature fell to the freezing point. The stratum of cold air must have been very thin, as the lowest temperature recorded by our voluntary observer at Kenton was 46°. His thermometers were not over six feet above the surface of the ground. We believe that if a large number of small or a few large fires had been built in different parts of the marsh a mixing of the air would have been produced sufficient to prevent formation of frost conditions.

The frost seems to have covered Hardin County and the neighboring portions of Allen, Hancock, and Marion counties. The morning map of Friday, June 30, shows that an area of high pressure was, at 8 a. m., central 100 miles northwest of this region, and the winds at Toledo and Columbus were northerly, with a velocity of 5 or 6 miles per hour. The special frost area seems to the Editor to represent not merely a region where cool air was formed by radiation and settled quietly to the ground, nor yet simply a region where the leaves of the plants cooled by radiation because the sky was clear. We have already explained in the MONTHLY WEATHER REVIEW, Vol. XXIV, p. 14, and in our "Preparatory Studies," Report of the Chief Signal Officer, 1889, p. 34, that in the middle of an area of high pressure, masses of air that are already specially cooled are descending to the ground and spreading out horizontally, forming spots of low temperature quite analogous to the inverse phenomenon, when special masses of warm moist air rise high enough to dot the sky with clouds here and there. We are inclined to think this third consideration is important and that such a mass of cold air descended upon northwestern Ohio and spread a little outward in all directions. Similar masses were descending by day and by night throughout the central high pressure area but only a few could produce destructive frost. Any one may see a similar phenomenon on a clear, warm, summer day when, in the midst of a calm period, the dust and leaves are suddenly observed to be blowing in all directions away from a central spot, and one must perceive at once that there has been a rapid descent of a small mass of denser air (it may have been drier or it may have been cooler), which, on reaching the ground, spreads outward and carries with it the dust and leaves.

CHALK-PLATE MAPS.

Not long since we had occasion to praise the excellent appearance of the maps published by the chalk plate process in the various monthly reports of the Climate and Crop Service, among which those published for Virginia particularly deserved commendation. The maps in the various reports for the month of June, 1899, showed many excellent features. We particularly wish to commend the pleasing effect of the green base and red isotherms in the New England report. The very clear print of the corresponding map in the Wisconsin report, and that for Ohio which is almost equally impressive. The black base map with red lines or the blue base with red lines seem to be the favorites, but the golden base with black lines and the green base with red lines strike us as being harmonious combinations that are also well worthy of trial. The Editor will be glad to hear from those experienced in these matters as to the relative advantages and difficulties in connection with different colored inks and qualities of paper.

TORNADO PHENOMENA.

Low Pressure.—The tornado that passed through New Richmond, Wis., on June 12, is quite fully described in the report of that section for June by Mr. W. M. Wilson, Section Director. Its path was from the southwest to the northeast, and it destroyed nearly the whole of the business portion of the town. Illustrations of the force of the wind are abundant, especially the fact that a large iron safe weighing 3,000 pounds was caught up and carried several hundred feet (possibly it was carried by the flooring on which it stood). Everywhere was to be seen convincing proof that the sudden lowering of atmospheric pressure over a small area was often the primary cause of destruction. Of course, there is no record of the

amount of the barometric depression, but in many cases a glance at the photographs shows that the houses were burst apart by the expansion of the air within. The weakest joints gave way and the walls fell outward flat to the ground; the depression lasted but a few seconds; there was no resulting wind; light and fragile materials within the rooms were not disturbed, but the roofs were sometimes carried a little way before they rested on the ground. Evidently, the expansion could only work outward and upward. The violent wind was at some height above the ground, and had such a definite limit that the upper part of a building was destroyed while the lower part was untouched by it. The gusty streaks of wind flew over the earth in some places, but grazed it in others. Regions thus affected would represent either the little whirls outside of the main tornado, or the places where the lowest end of the main whirl temporarily rose above the house tops. An outward pressure of one pound per square inch over the whole side of a house corresponds to a barometric pressure within the house greater than that outside, by about two inches of mercury, and would disrupt these slightly built frame houses, whose beams are held in place by only a few nails and wooden pegs.

When a severe wind blows past any obstacle there is a slight increase of pressure on the windward side and a diminution on the leeward. The maximum amount of the increase is given by the formula $P - P_0 = 0.0000383 \times V^2$, where $P - P_0$ is the increase in pressure expressed in inches and V is the velocity of the wind expressed in miles per hour. Therefore, for a velocity of 100 miles per hour the rise of pressure will be 0.383 inch. On the leeward side of the obstacle the diminution of pressure depends so much upon the shape of the surface that no calculation can be made, but the depression on this side may be nearly as great as the excess of pressure on the windward side if the body has the requisite shape. But the photographs show that in many cases no such wind prevailed at the time that these houses were exploded; in fact, sometimes the explosion occurred just before the wind came, and in some cases it was not even followed by any wind. Therefore, the bursting of these houses is not due to wind blowing against or through or past them.

It seems plausible that a tornado begins with a local low pressure within a buoyant cloud in regions high above the ground. As the air flows upward into this low pressure and acquires a more or less violent rotary motion the surfaces of equal pressure descend toward the earth's surface about as figured by Ferrel in his theory of the waterspout and tornado. The tornado funnel cloud represents the core of the system of whirling ascending winds and funnel-shaped isobaric surfaces; the depression in the cloudy interior may be as much as 3, 5, or even 10 barometric inches, but outside of the funnel cloud and near it a depression of 2 inches and farther away 1 inch must exist in the clear air. Below the funnel, between its end and the ground, such depressions will cause a destructive upward wind, but not a horizontal wind, and that too for a second only, as the spout moves about irregularly in the air, sometimes descending to the surface of the ground and at other times retreating to the clouds. The space immediately about the spout or funnel is undoubtedly occupied by rapidly rotating and ascending air, but as the rotation and the funnel extends downward toward the ground, the relatively quiet air beneath can not be set into horizontal rotation so easily as it can be pushed upward into the axis of the funnel. We thus perceive how a system of whirling winds and low pressure sometimes works rapidly downward above a house so quickly that the air within the house lifts the roof up, leaving the walls standing, while the whirling funnel passes onward, and its winds are not felt severely at that spot. Again, the whirl having already reached the ground may pass near a building, temporarily diminishing the pressure on one side and allowing that to burst outward on the side toward the tornado, while only a slight wind affects the building. Finally, the winds that feed a fully developed tornado can not flow toward it in straight lines, but must themselves have smaller eddies and whirls and even funnel spouts, so that buildings at some distance from the path of greatest destruction may be injured by these subsidiary whirls.

The path of destruction of a tornado will vary in width from a few rods to a half mile (160 rods). In the central portion of this path the violent winds generally obliterate all traces of the explosive action due to the sudden approach of a barometric depression, but on the outer edges of the path less violent winds occur, and the evidences of explosion are frequently visible in the débris after the storm has passed.

It does not require any great fall of the barometer on the outside of the house in order to tear apart these wooden frame buildings; for instance, in a room 20 feet square and 10 feet high, whose outside wall is held to the central frame of the house by means of large nails 6 inches apart, we have to consider only 120 nails distributed around the 60 feet that form the four edges of the outside wall. If it requires 200 pounds to pull one of these nails out of its setting, we have a total pressure of 12,000 pounds distributed over the surface of the room, which is 200 square feet, therefore, an average of 60 pounds to the square foot, or less than 3 pounds to the square inch. Now, the ordinary barometric pressure of 15 pounds to the square inch, when the barometer is 30 inches high, is diminished by 3 pounds, and becomes 12 pounds to the square inch when the barometer falls 6 inches, or when it stands at 24 inches instead of 30. This corresponds very closely to the barometric pressure inside of a thunder cloud at 5,000 feet above the earth's surface. It is a pressure that can easily occur inside of a whirling waterspout or tornado. If the lower end of a cylindrical whirl of wind, within which such a low pressure prevails, passes over any given building in such a way that the air around the building rushes up to enter the whirl, then the air within the building can not escape fast enough through the chimneys and cracks. If the doors and windows are not opened in time the roof will rise or the weakest side burst outward. Even in ordinary storms the Editor has seen the loose trap door on the roof of his house, rise up, and thereby afford escape for the air within.

On Plates I, II, and III we reproduce three photographs illustrating the explosion of houses without the concurrence of any wind to disturb the interiors. We are indebted for these to Mr. H. J. Volker, Observer, Weather Bureau, St. Paul, Minn., who obtained them from Hass Bros., photographers, with permission to republish. Mr. Volker writes as follows:

> These photographs illustrate the fact so often emphasized by the Weather Bureau that buildings are not always blown down or wrecked from without, but are burst from within, upon release from outside atmospheric pressure. The sides or walls of all three wrecks show that they fell outward. The photographer's opinion is, that perhaps the chairs in No. 10 had been set up after the storm. He is sure the boards were nailed on the windows on the west side of No. 12, and he believes nothing was disturbed in No. 22 the bay window of which lies to the east. The views show clearly, that in the absence of a cellar, the center of a room is sometimes the safest place.

LOCAL WINDS THAT ARE NOT TORNADOES.

During the summer season very many local storms pass over all portions of this country without developing into typical tornadoes. In some cases the atmospheric conditions are such that a genuine tornado would be scarcely possible; in other cases, when the atmospheric conditions are favorable, the peculiarities on the surface of the ground may contribute to prevent the formation of the whirl and resulting fun-